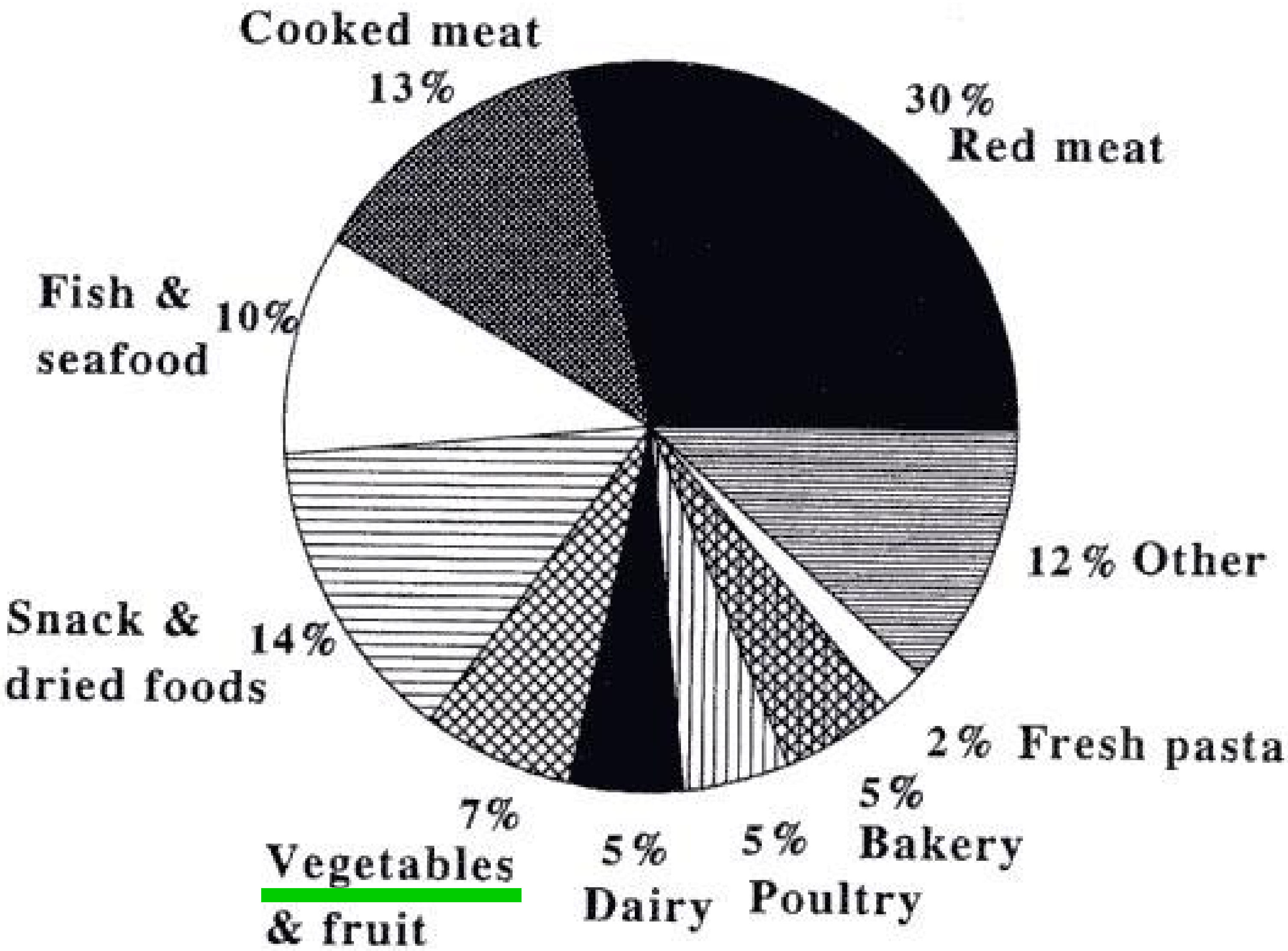
Modified Atmosphere packaging for Fruits and Vegetables

E. Sfakiotakis

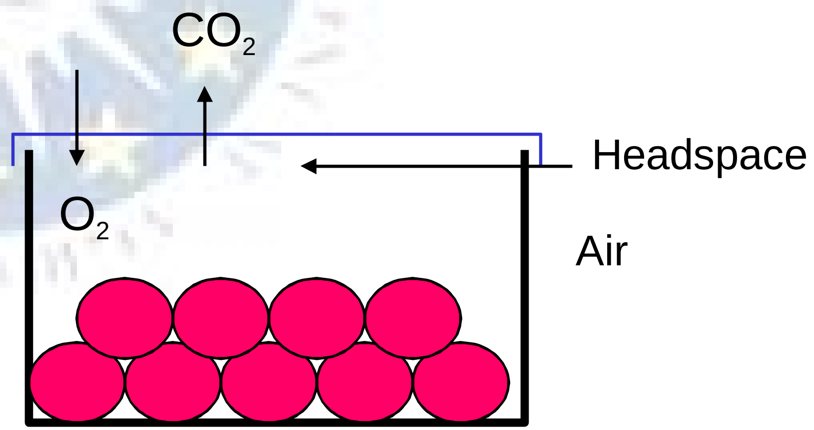
- Introduction
- Methods to create MAP conditions
- Application of MAP for Fruits and Vegetables (advantages and disadvantages, extrinsic factors to optimise)
- Effects of MAP on pathogen and quality of F&V
- Packaging machinery
- Films for MAP
- Future prospects

Segmentation of the UK MAP retail market by food sectors (1992)



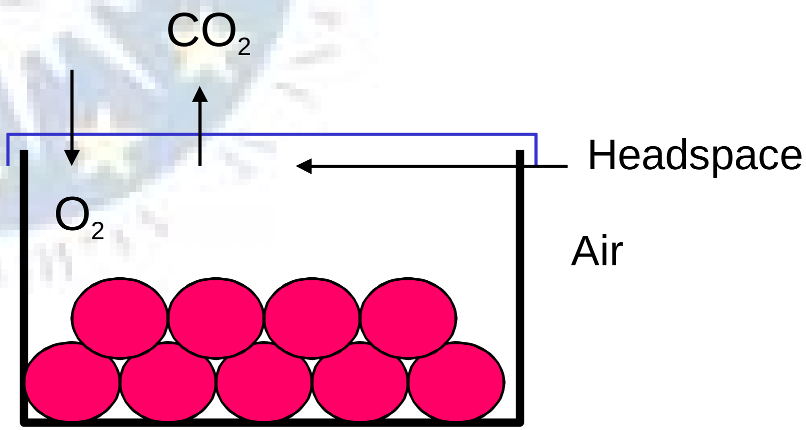
Modified atmosphere packaging (MAP)
A form of packaging involving the removal of air from the pack and its replacement with a mixture of gases

- The gaseous atmosphere changes continuously throughout storage period due to factors (respiration, biochemical changes and the slow permeation of gases through the container)



The goal of MAP is to:

- reduce water loss
- generate an atmosphere sufficiently low in O_2, or high in CO_2 to influence the metabolism of the product being packaged or the activity of the decay-causing organisms resident on the product such that storability and/or shelf life is extended
- Improves moisture retention
- Reduced O_2 retards textural and flavor changes
- Elevated CO_2 (8-25%) reduces fungal decay and preserves the green color
- Maintaining a product sealed-off from the external environment helps reduce exposure to airborne pathogens



Advantages of MAP

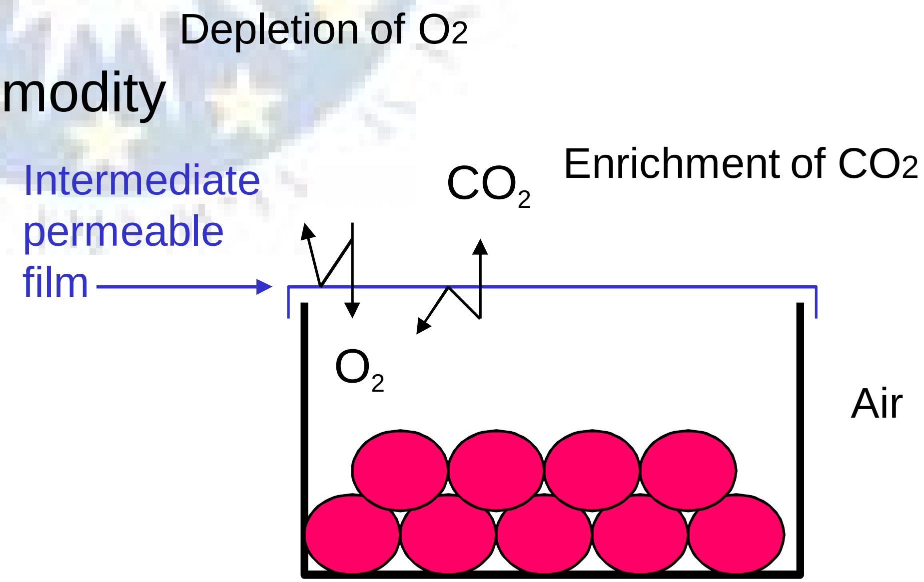
- reduces respiration
- delay ripening
- decrease ethylene production and sensitivity
- retard textural softening
- slow down compositional changes (chlorophyll degradation, enzymatic browning)
- alleviate physiological disorders and chilling injury, maintain colour
- preserve vitamins
- results in extended shelf-life

Disadvantages of MAP

Outside from limits of tolerance of O_2 and CO_2 for the particular commodity

Incorrectly designed MAP may even shorten the shelf life

- Initiates anaerobic respiration
- Undesirable odours and flavors
- Physiological disorders



Gaseous composition of dry air

N_2: 78.03%, O_2: 20.99%, Argon: 0.94% , CO_2: 0.03%, Hydrogen: 0.01%

Gases used in MAP

O_2, CO_2 , N_2 , SO_2 , CO ?

The role of gases in MAP

Oxygen will stimulate the growth of aerobic bacteria and can inhibit the growth of anaerobic bacteria.

Nitrogen is an inert tasteless gas, used to replace oxygen in the packs. Because of low solubility used as a filler gas to prevent packs collapse (from high CO_2).

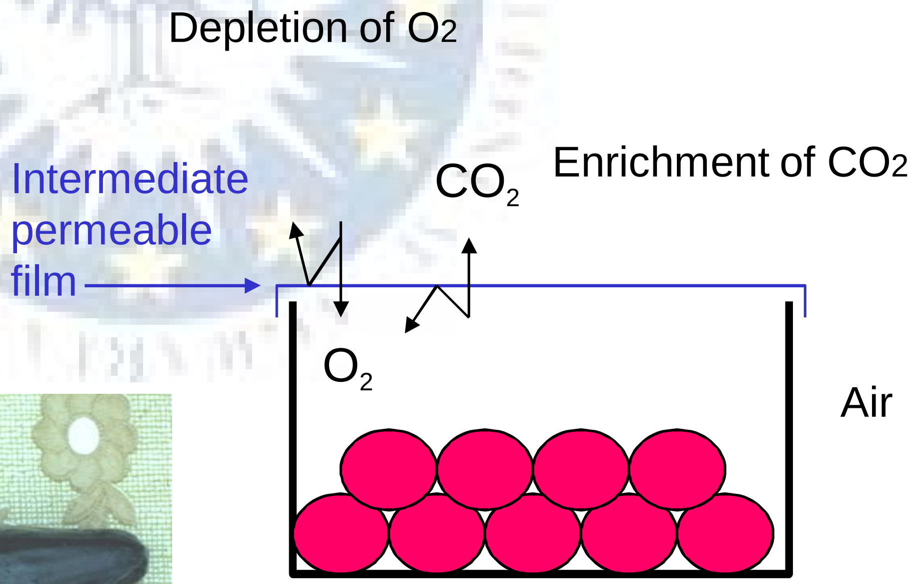
Carbon dioxide is water- and lipid-soluble responsible for the fungistatic and bacteriostatic effects (extension of the lag phase of growth and a decrease in the logarithmic phase. Furthermore delays ripening and senescence of the host product.

MAP in Fruits and vegetables

Scenario A

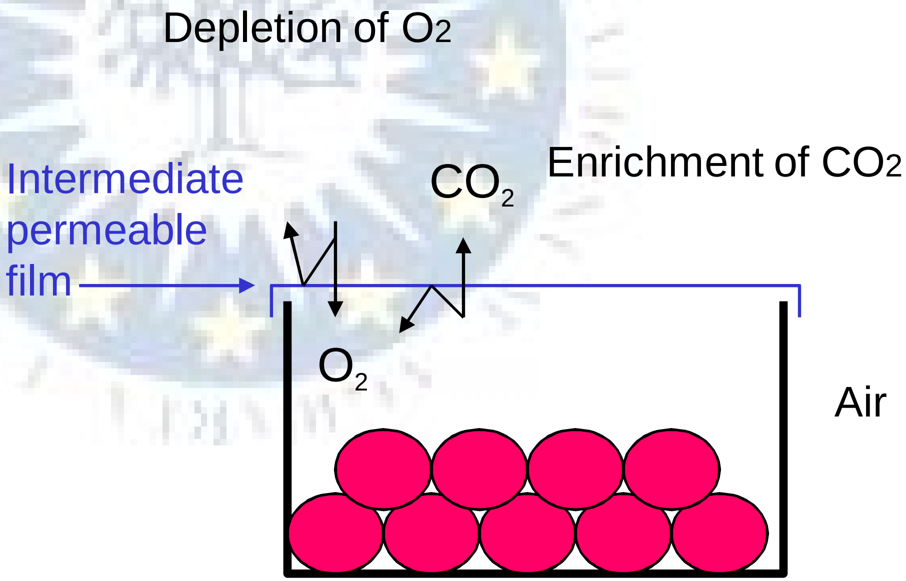
If produce is sealed in an impermeable film the O_2 level will fall to very low concentration where anaerobic respiration will initiated

- Accumulation of ethanol, acetaldehyde and organic acids
- Undesirable odours and flavors
- There is a risk of growth of anaerobic pathogens (*Clostridium botulinum*)



Scenario B

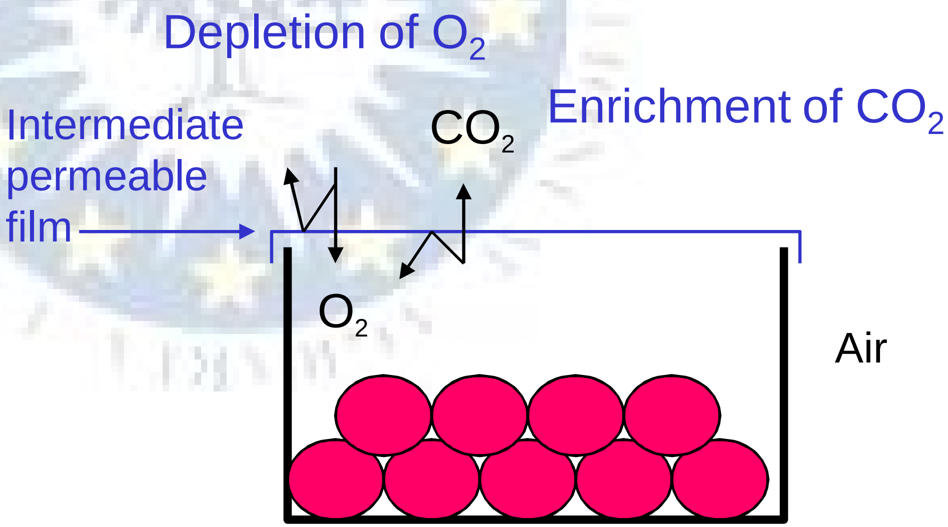
If produce is sealed in an a film of excessive permeability little or no atmospheric modification will result within the package
Loss of moisture



Scenario C

If produce is sealed in an a film of correct intermediary permeability a desirable equilibrium modified atmosphere (EMA) is established when the rates of O2 and CO2 transmission through the package equal the product 's respiration rate

The EMA attained will depend on the product's respiration rate but will be also be influence by extrinsic factors (stage of maturity, mechanical injury, temperature, relative humidity)



Optimal equilibrium gas level

An optimal equilibrium modified atmosphere (EMA) should minimise respiration rate without danger of physiological damage to the commodity

EMAs containing between 2-5% O_2 and 3-8% CO_2 extends the shelf -life of a wide variety of fruit and vegetables

CA/MA recommendations for fruits

Commodity	Temperature range (deg. C)	Reduced O_2%	Increased CO_2%
Apricot	0-5	2-3	2-3
Avocado	5-13	2-5	3-10
Banana	12-16	2-5	2-5
Blackberry	0-5	5-10	15-20
Blueberry	0-5	2-5	12-20
Cherry sweet	0-5	3-10	10-15
Grape	0-5	2-5	1-3
Kiwifruit	0-5	1-2	3-5
Lemon	10-15	5-10	0-10
Orange	5-10	5-10	0-5
Peach	0-5	1-2	3-5
Raspberry	0-5	5-10	15-20
Strawberry	0-5	5-10	15-20

Methods of atmospheric modification

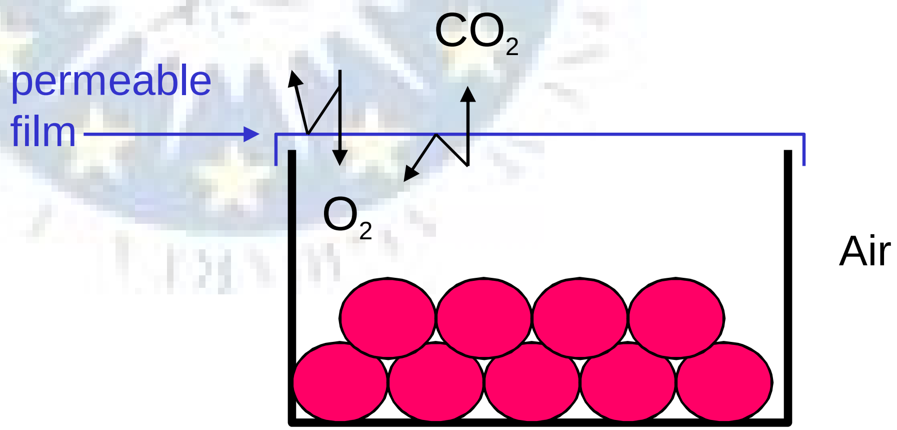
Modified atmosphere generation by:

Passive modified atmosphere

Via active packaging

Vacuum packaging

.

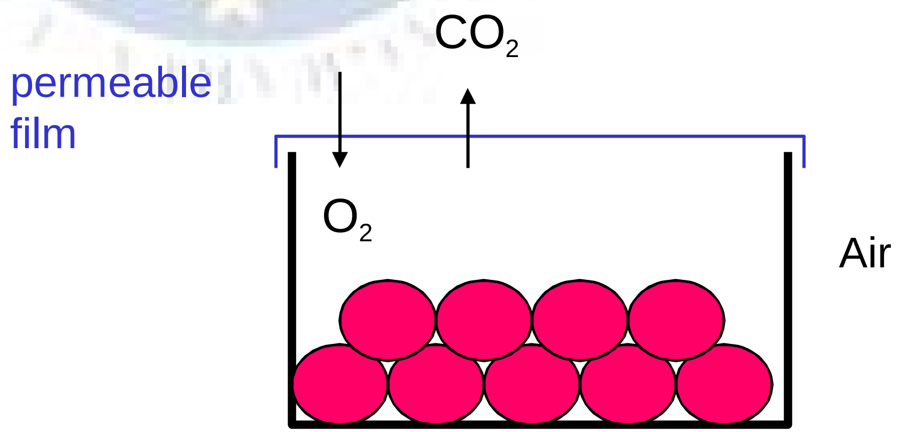


Methods of creating MA conditions

Passive modified atmosphere

fruits and vegetables continue to respire after harvest, they consume oxygen and producing carbon dioxide and water vapor.

If film of correct intermediary permeability is chosen, the a desirable EMA is established when the rates of O2 and CO2 transmission through the package equal a product ’s respiration rate



Active modified atmosphere

Actively establish and adjust the atmosphere within produce package

By pulling a slight vacuum and replacing the package atmosphere with a desired mixture of O2 and CO2 and N2, a beneficial EMA may be established more quickly than the passively generated EMA .

Gases used in MAP

O_2, CO_2 , N_2 , SO_2 , CO ?

The role of gases in MAP

Oxygen will stimulate the growth of aerobic bacteria and can inhibit the growth of anaerobic bacteria.

Nitrogen is an inert tasteless gas, used to replace oxygen in the packs. Because of low solubility used as a filler gas to prevent packs collapse (from high CO_2).

Carbon dioxide is water- and lipid-soluble responsible for the fungistatic and bacteriostatic effects (extension of the lag phase of growth and a decrease in the logarithmic phase. Furthermore delays ripening and senescence of the host product

Processes occurring simultaneously

Respiration of the produce

(temperature, produce maturity, CO2 and O2, C2H4)

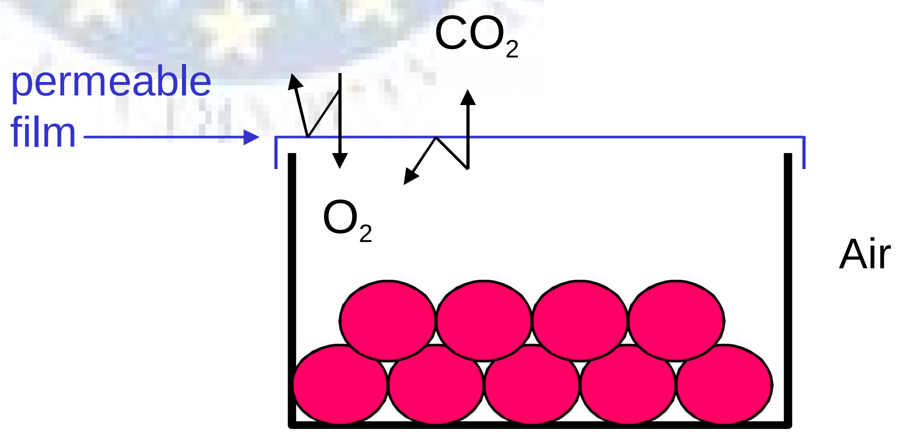
Transpiration of the produce

(surface temperature, temperature and RH of the surroundings)

Permeation of gases

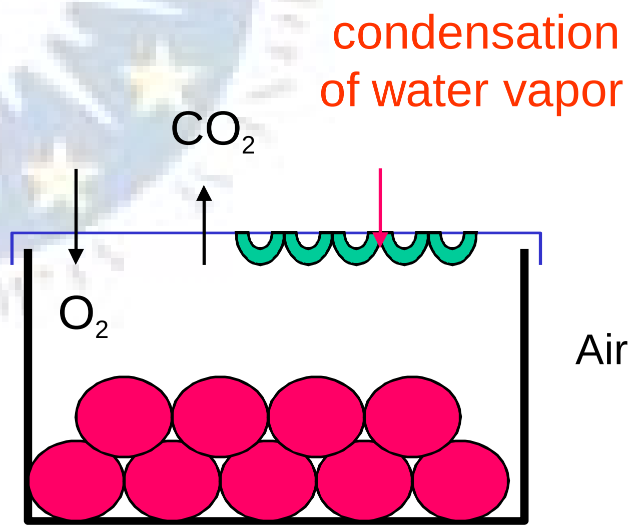
(chemical makeup of the film, ambient temperature, film thickness. Permeating gas, difference in gas composition across the film)

Heat transfer



Extrinsic factors to optimise

Harvesting
Handling
Hygiene
Temperature
Water loss and relative humidity
3-6% moisture losses cause market deterioration of quality



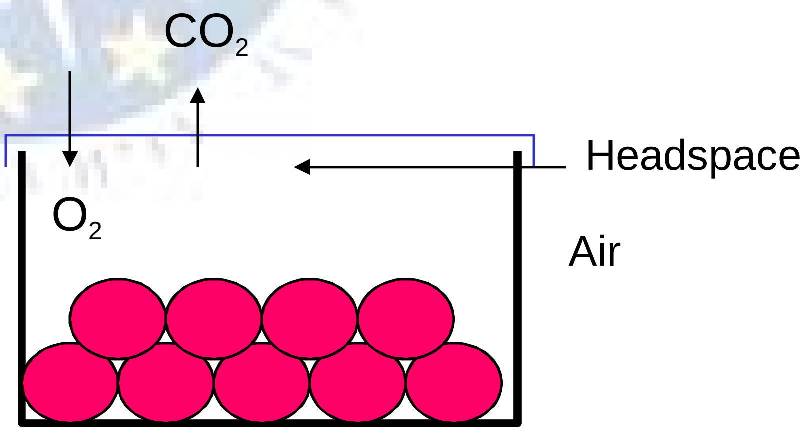
Temperature is extremely important consideration in package design.

The permeability of O_2 (or CO_2) through low density polyethylene (LDPE) increases 2.5 fold between 0 and 15°C

The product respiration increases at least TWICE as fast as LDPE permeability

This is the ‘temperature problem’ of MAP

Important to maintain strict control over the temperature of the packaged product-avoiding the limitations imposed by the film



Solving the «temperature problem»

Using «package O_2 model» by combining information on the effect of temperature on film permeability with information on the effect of T° and O_2 on respiration.

Critical factors to consider to construct the «package O_2 model»

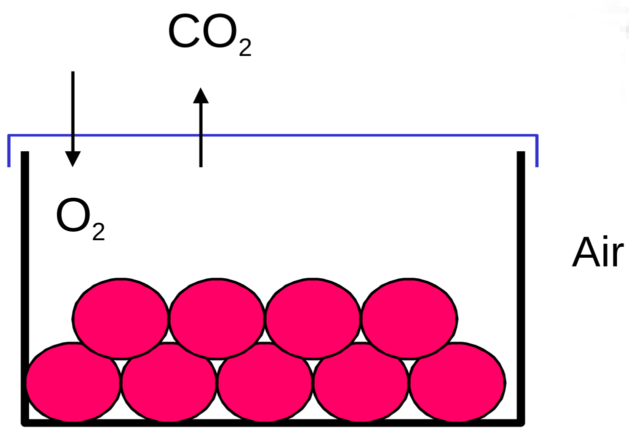
- temperature,
- fruit weight,
- surface area and
- film thickness

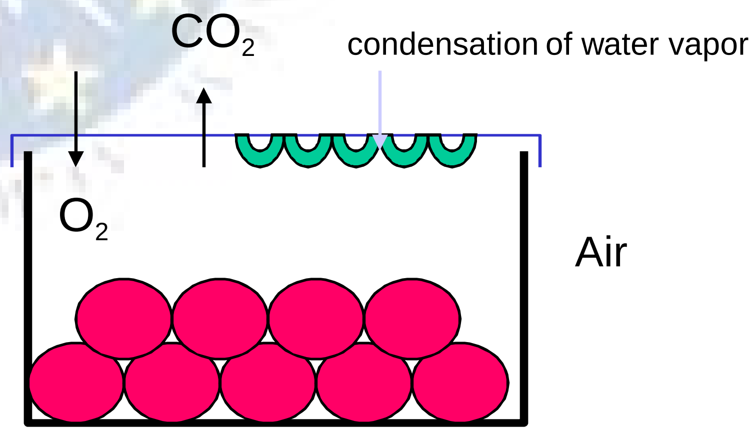
Extrinsic factors to optimise

Packaging material

Packaging machinery

Gas/product ratio is approximately in the range 3:1 to 1:1



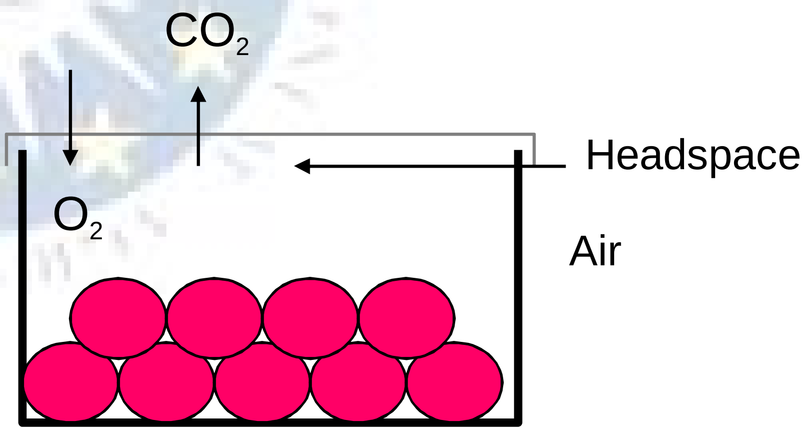


If O_2 levels decline below a critical concentration to sustain aerobic respiration. Fermentation and off-flavor may result.

If CO_2 concentration exceeded a level tolerance by the plant tissues, injury is likely to occur

Berry crops are more tolerant to high CO_2 (10%) than most commodities

Commodity	Temperature range (Æ)	Reduced O2%	Increased CO2%
Apricot	0-5	2-3	2-3
Avocado	5-13	2-5	3-10
Banana	12-16	2-5	2-5
Blackberry	0-5	5-10	15-20
Blueberry	0-5	2-5	12-20
Cherry sweet	0-5	3-10	10-15
Grape	0-5	2-5	1-3
Kiwifruit	0-5	1-2	3-5
Lemon	10-15	5-10	0-10
Orange	5-10	5-10	0-5
Peach	0-5	1-2	3-5
Raspberry	0-5	5-10	15-20
Strawberry	0-5	5-10	15-20



Postharvest disease suppressions by MAP

Examples:

Strawberries

An initial charge of CO_2 plus the produced by respiration served to maintain the CO_2 -enriched concentration of CO_2 during transit of film-covered pallets of California strawberries

Incidence of decay at 15°C was lowest when CO_2 concentration upon arrival were >10% and transit temperatures were < 3°C.

Combining preharvest fungicidal sprays-applied during the flowering season-with suitable PVC wraps almost eliminated pathological deterioration during prolonged storage

Postharvest disease suppressions by MAP

Examples:

Tomatoes

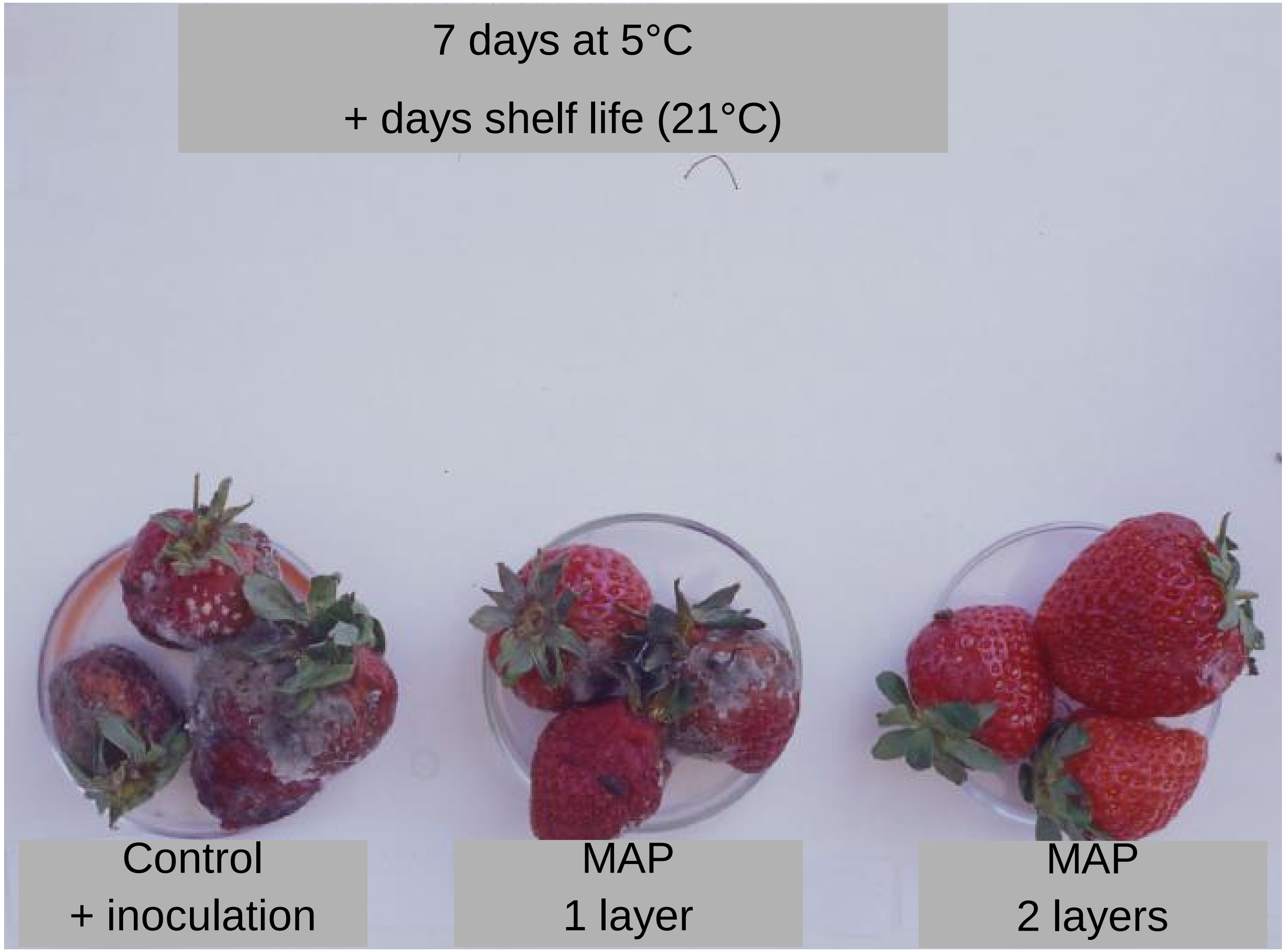
An initial charge of CO_2 plus the produced by respiration served to maintain the CO_2 -enriched concentration of CO_2 during transit of film-covered pallets of Morocco tomatoes

Effects of P MAP on pathogen and quality of F&V

Postharvest disease suppressions by MAP

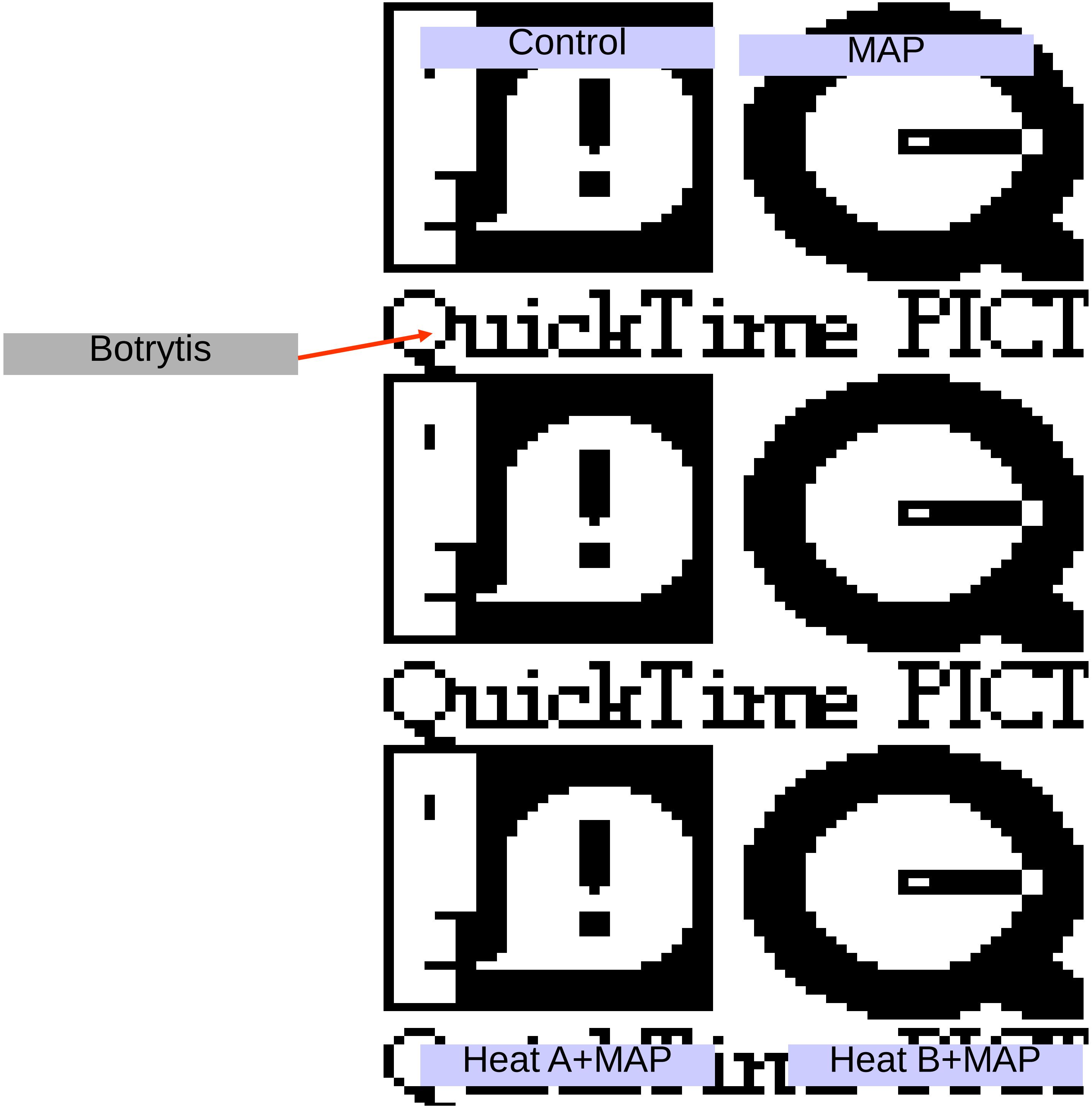
Examples:

Strawberries



Postharvest disease suppressions by MAP

Examples:
Strawberries


Control
MAP
Botrytis
Heat A+MAP
Heat B+MAP

Factors affecting shelf-life (microbiology of MAP)

Shelf-life the period of time from harvest to consumption that a produce remain safe

Intrinsic properties of fresh produce

Respiration rate

Acidity (pH) Most fruits (lemons, oranges, pineapples, apples and peaches have a pH below 4.5. Under acidic conditions *Clostridium botulinum* cannot grow and produce its potential deadly toxin.

Most vegetables (lettuce, carrots, potatoes, mushrooms, broccoli) have pH values above 4.5 and consequently *Clostridium botulinum* is able to grow when such commodities are stored under anaerobic conditions.

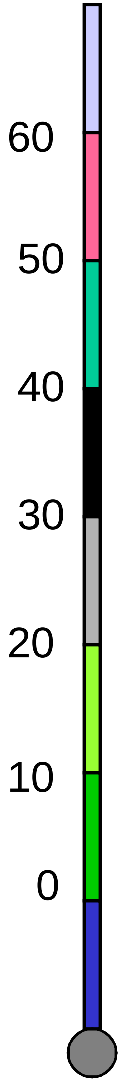
Storage temperature.*Clostridium botulinum* cannot grow at temperature below 3°C

Water activity. Use optimal chilled temperature and MAP to inhibit the growth of microorganism

Biological structure

Ethylene production and sensitivity

Relationship between temperature and growth and survival of microorganisms



Temperature above 80° are disinfecting -all microorganisms, except bacteria spores, are killed

KEEP HOT FOODS HOTTER THAN 60°C

Active growth of bacteria, yeasts and mould, including pathogens

KEEP COLD FOODS COLDER THAN 4°C

Postharvest disease suppressions by MAP

Conclusions on microbiology of MAP:

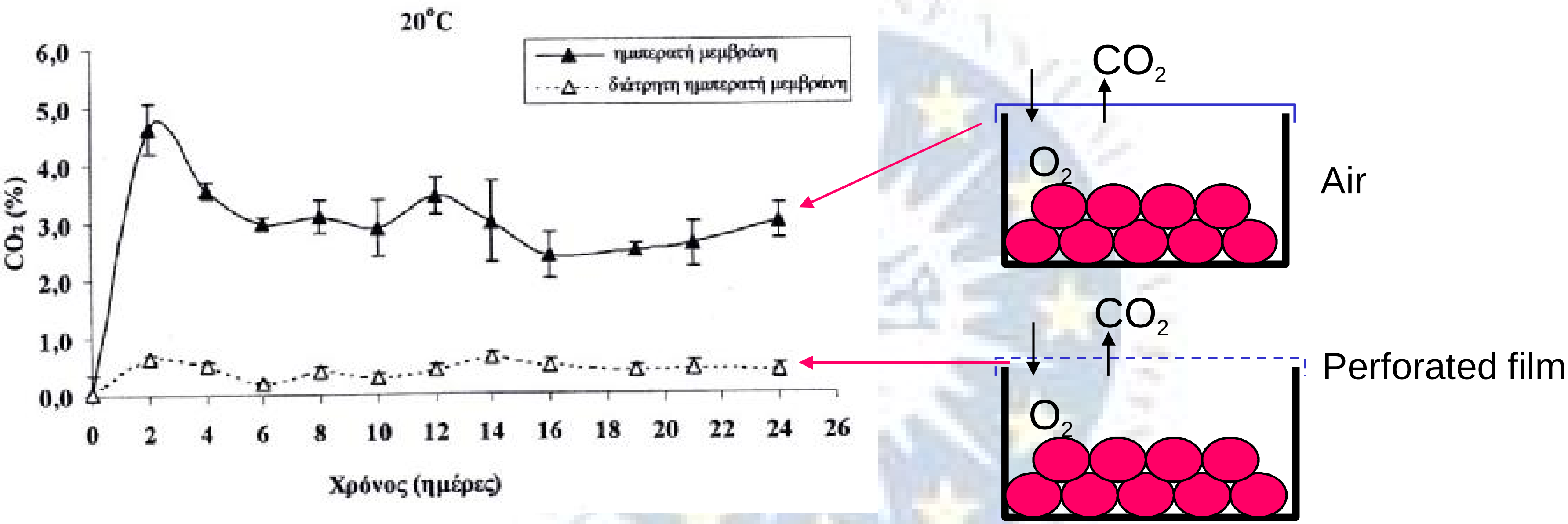
MAP can indirectly reduce postharvest diseases to a large extent, by maintaining host resistance via delaying the climacteric rise in fruit respiration and by inhibiting the onset of ripening and senescence.

Removal of ethylene from the storage atmosphere may farther reduce disease by leading to increased retardation in the ripening process.

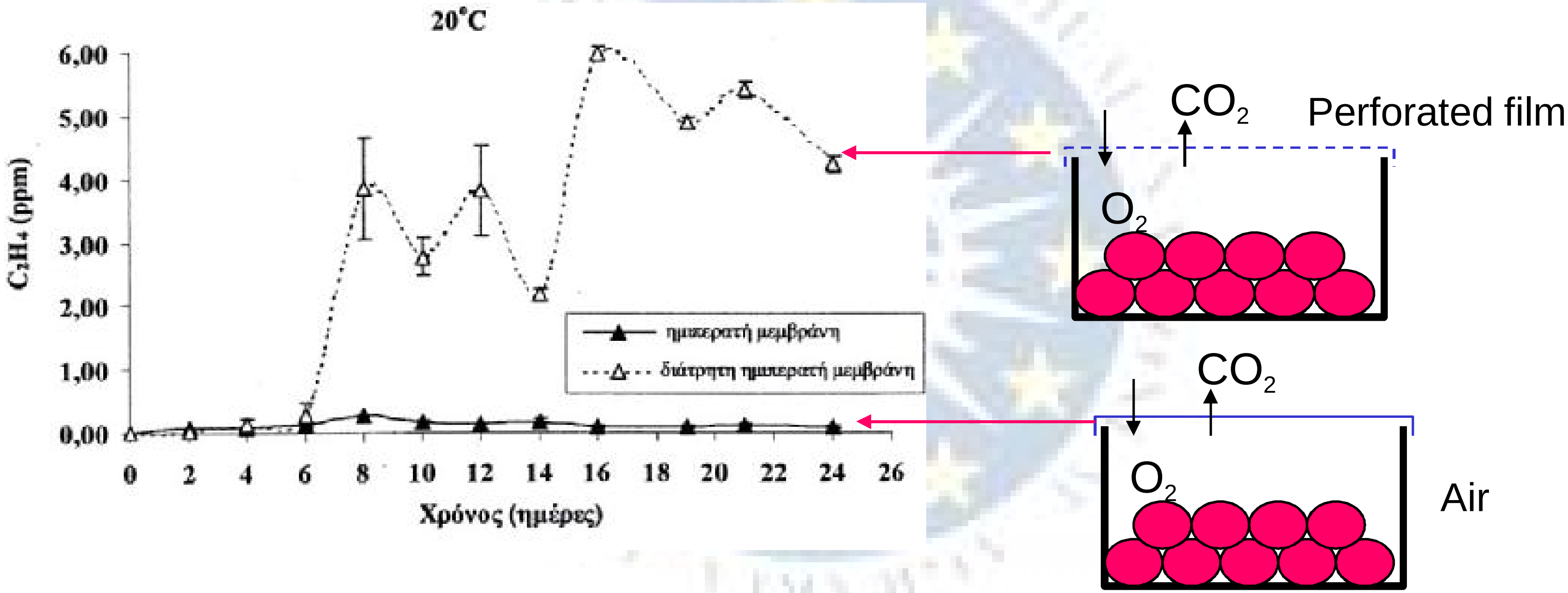
A reduced O_2 or elevated CO_2 level also has a direct inhibitory effect on pathogen growth.

For the berry crops (strawberries, raspberries etc) and sweet cherries that tolerate high CO_2 (20%) CO_2 applied during transit can suppress disease development both directly and by retarding physiological aging

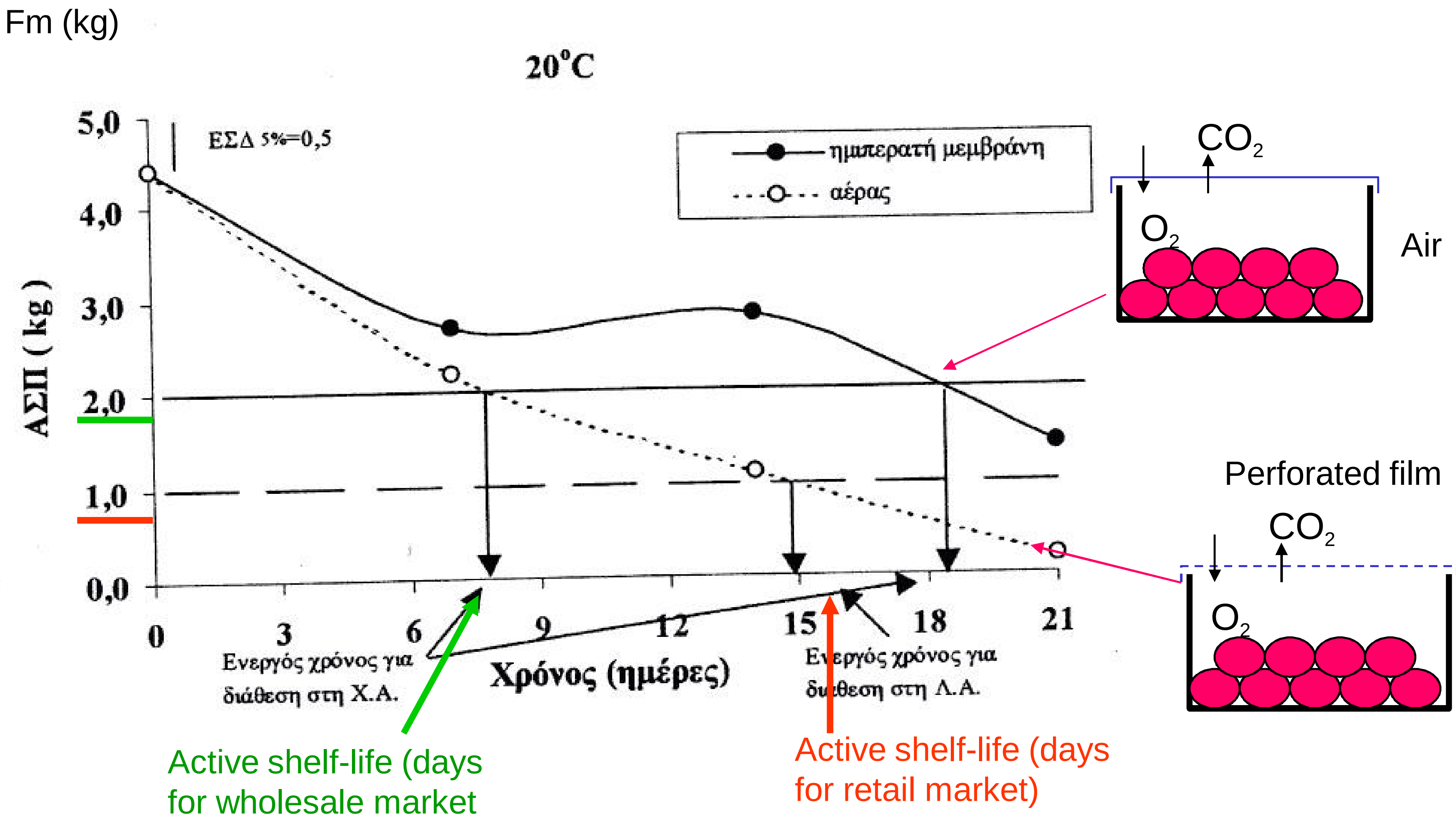
Effects on respiration



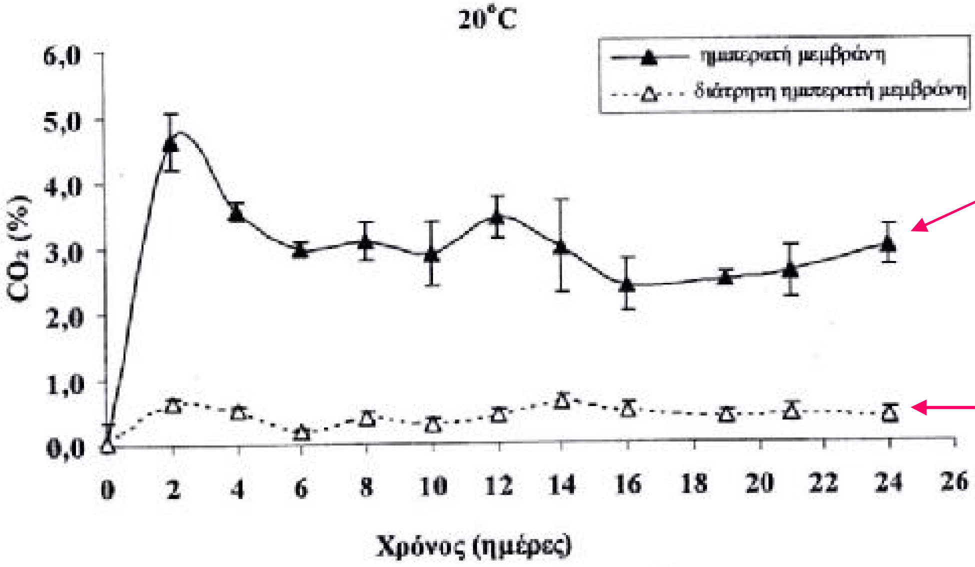
Effects on ethylene production

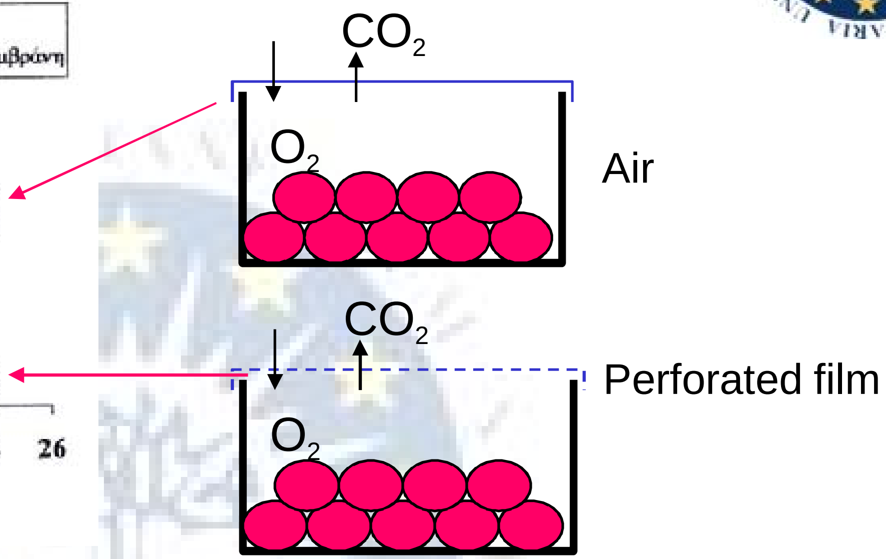


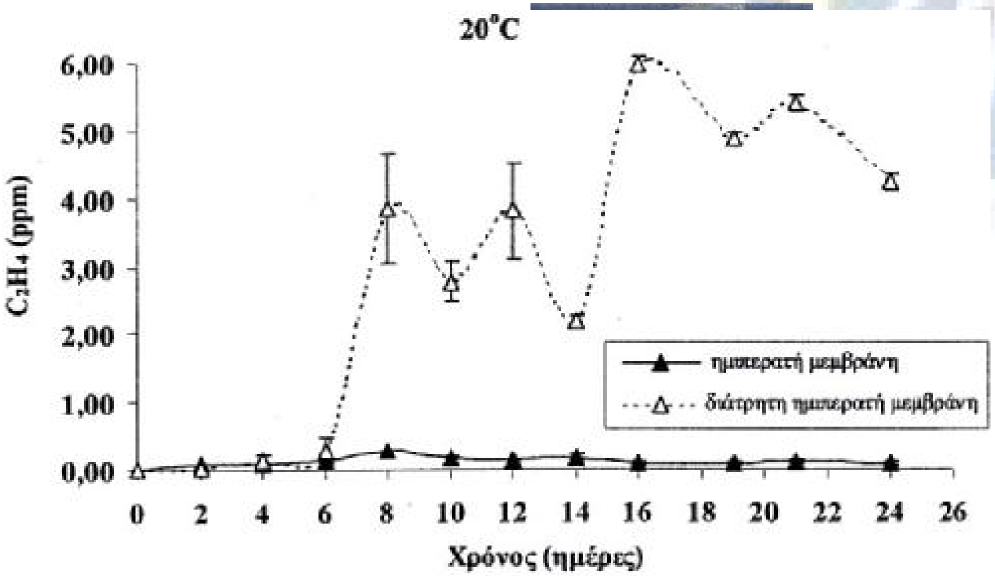
Effects on softening (20°C)



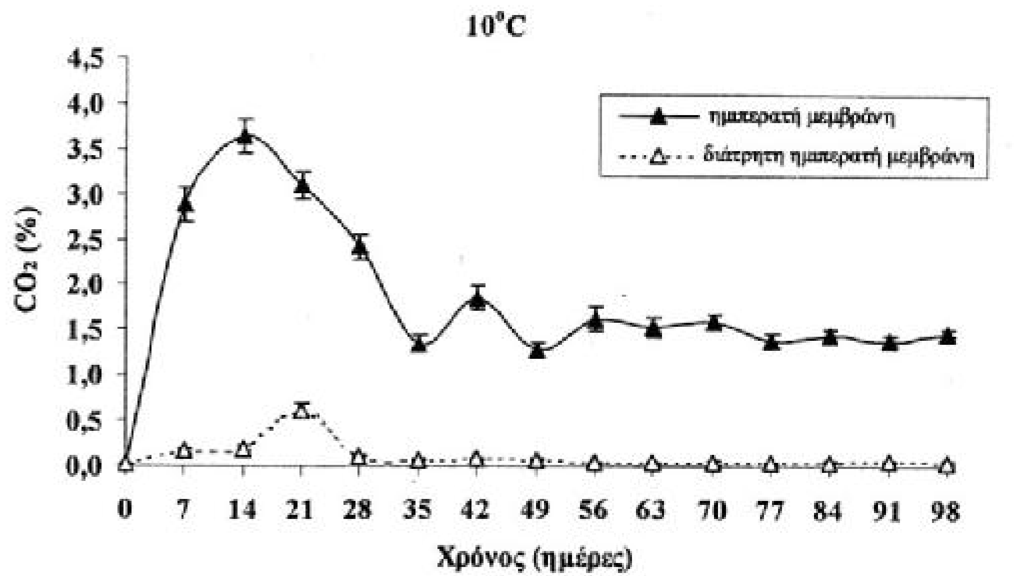
Effects on CO_2 and ethylene production (20°C)

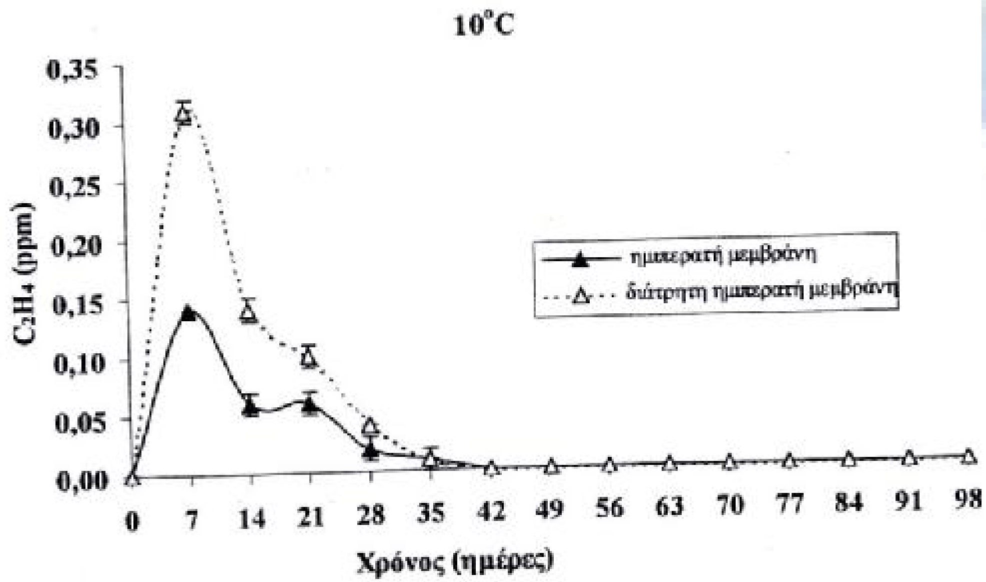






Effects on CO_2 and ethylene production (10°C)



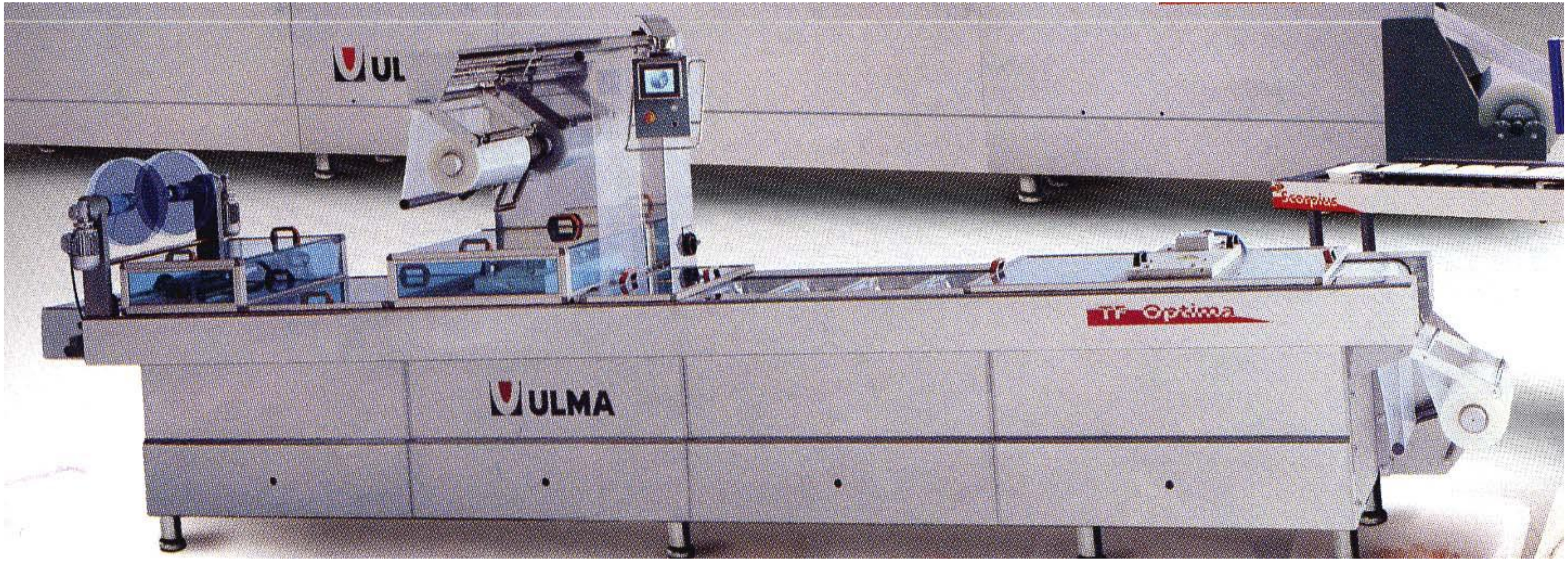


Packaging Machinery

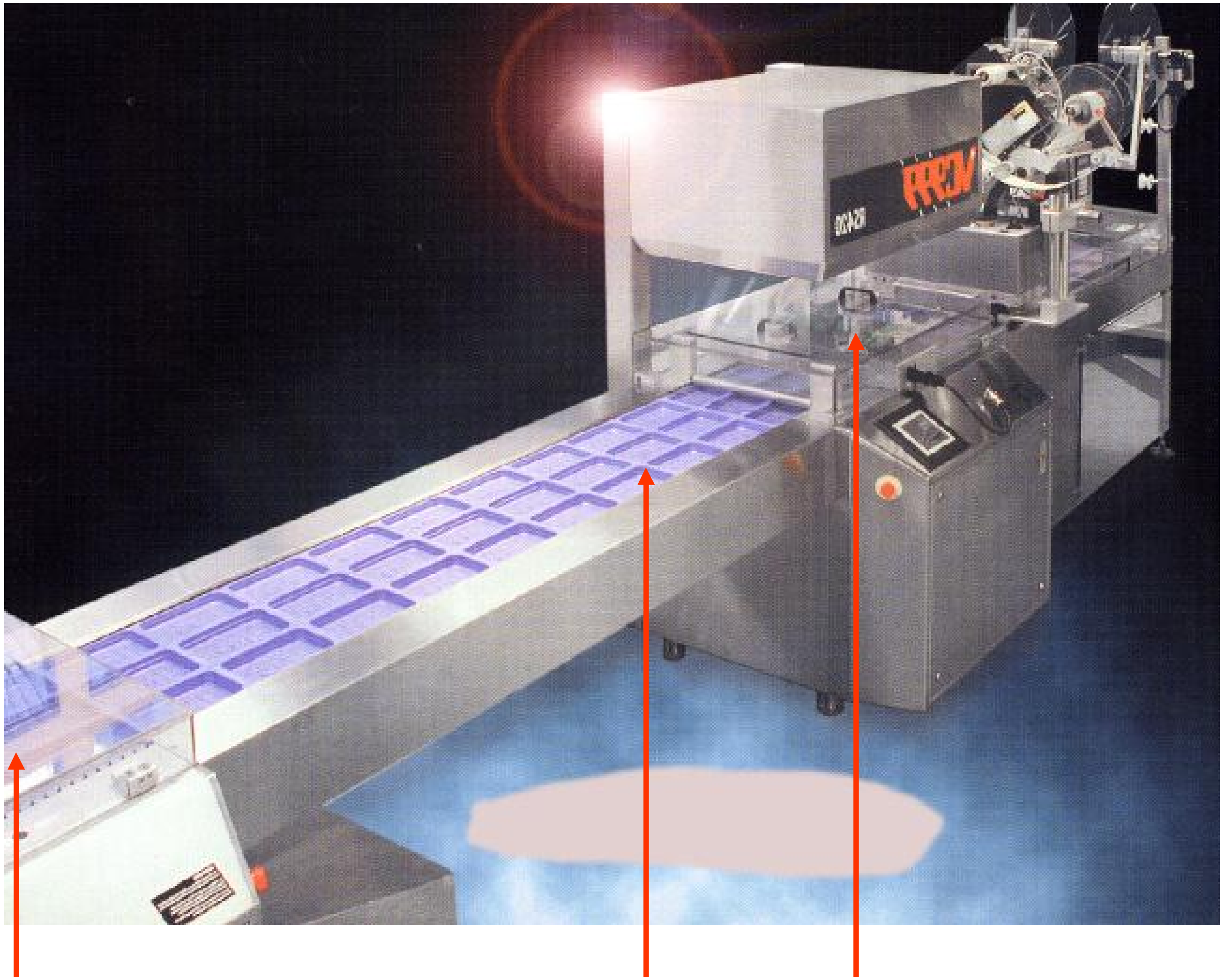
Vacuum packaging

The product is placed in a pack of lower oxygen permeability, air is evacuated and the package sealed. The gaseous atmosphere of the vacuum package is likely to change during storage (from metabolism of the product) and therefore the atmosphere becomes modified directly.

By pulling a slight vacuum and replacing the package atmosphere with a desired mixture of O_2 and CO_2 and N_2, a beneficial equilibrium MA may be established more quickly than the passively generated EMA.


ULMA
TF Optima
Scorpius

Packaging system for industrial mass-production



Film is formed into trays

Loading products

Vacuum packaging

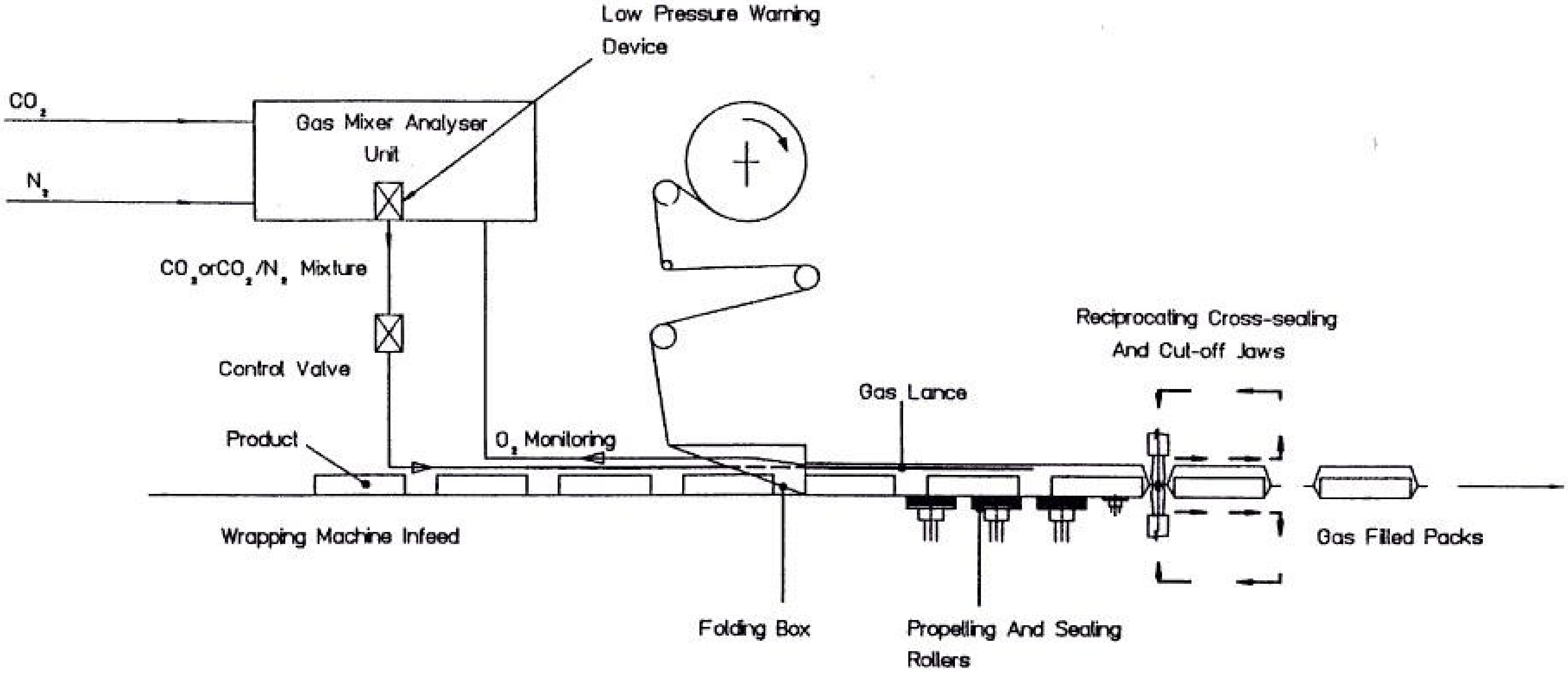


Figure 3.7 Conventional horizontal form-fill-seal machine with box-motion sealing head.

FILMS FOR MAP

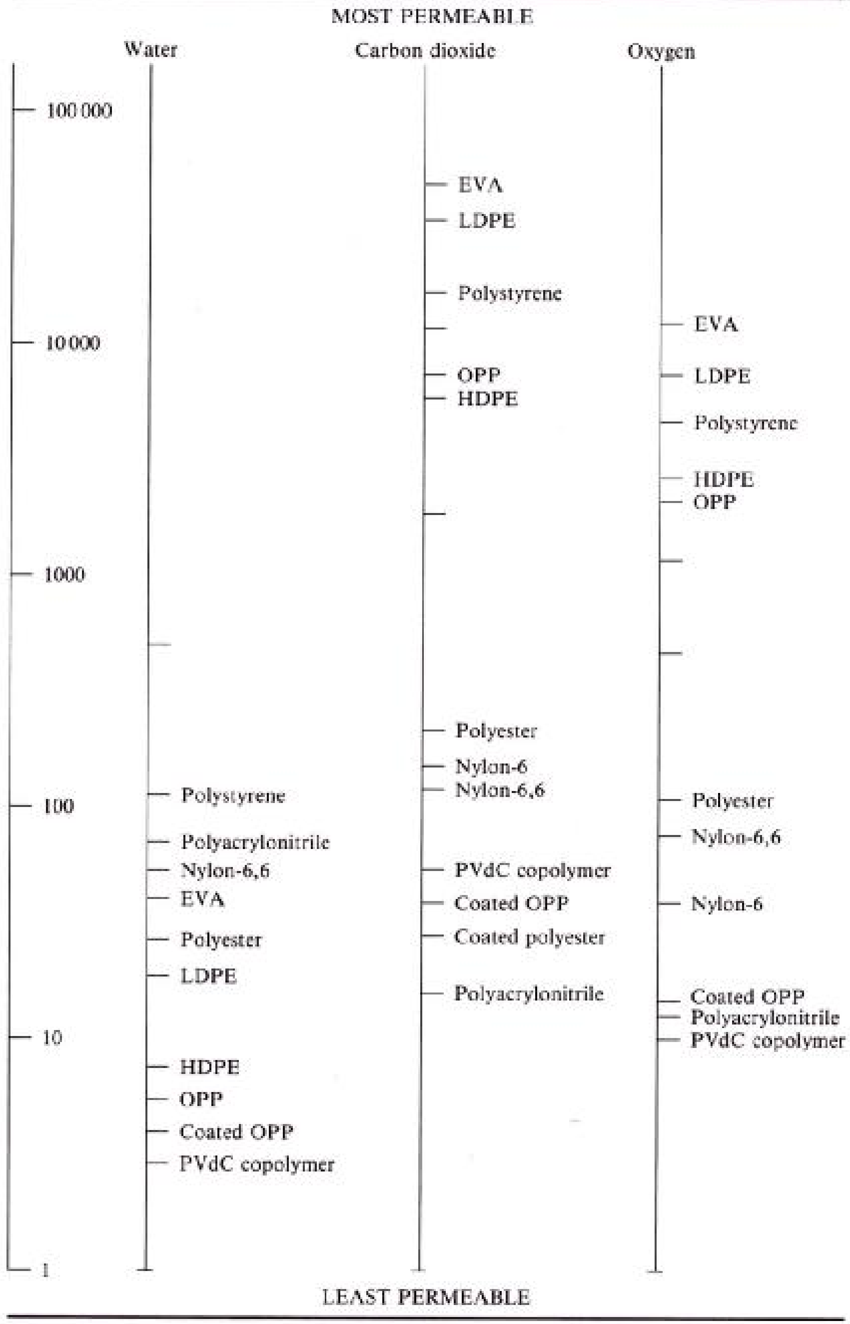
New developments in the design of high-permeability films for packaging of F&V. Films in which moisture and gas permeability change under specific temperature conditions to match or exceed the respiratory rate of the product (retain packs)

Table 4.1 Basic film barriers

Films	Water vapour transmission (g/m^2.day at 38°C and 90% RH)	Gas permeability (cm^3/m^2.day.atm for 25 mu film at 25°C)			Oil and grease resistance*
		Oxygen	Nitrogen	Carbon dioxide	
Polyester, oriented	25–30	50–130	15–18	180–390	E
Polyester, oriented PVdC coated	1–2	9–15	—	20–30	E
Nylon-6	84–3100	40	14	150–190	E
Nylon-6,6	45–90	78	6	140	E
Nylon-11	5–13	500	52	2000	E
Polyurethane (polyester)	400–600	800–1500	600–1200	7000–25000	E
Polystyrene, oriented	100–125	5000	800	18000	G
APET	40–50	110–130	—	—	E
CPET	Permeabilities change according to level of crystallinity. For each 1% change in crystallinity there is a 1.5% improvement in transmission rate.				E
EVOH	16–18	3-5	—	—	—
Rigid PVC	30–40	150–350	60–150	450–1000	E
Plasticised PVC	15–40	500–30000	300–10000	1500–46000	G
PVdC–PVC copolymer (Saran)	1.5–5.0	8–25	2–2.6	50–150	E
Polyacrylonitrile	78	12	3	17	G
Polyethylene, LD	18	7800	2800	42000	P
Polyethylene, HD	7–10	2600	650	7600	G to E
Polypropylene, cast	10–12	3700	680	10000	G
Polypropylene, oriented	6–7	2000	400	8000	G to E
Polypropylene, oriented, PVdC coated	4–5	10–20	8–13	35–50	E
Polybutylene	8–10	5000	—	—	G
Ionomer	25–35	6000	—	6000	E
Ethylene-vinyl acetate	40–60	12500	4900	50000	P

* E, excellent; G, good; P, poor.
RH, relative humidity.

Table 4.2 A simple guide to range of barrier properties of plastic films



The future

Considerable potential for MAP development and implementation commercially.

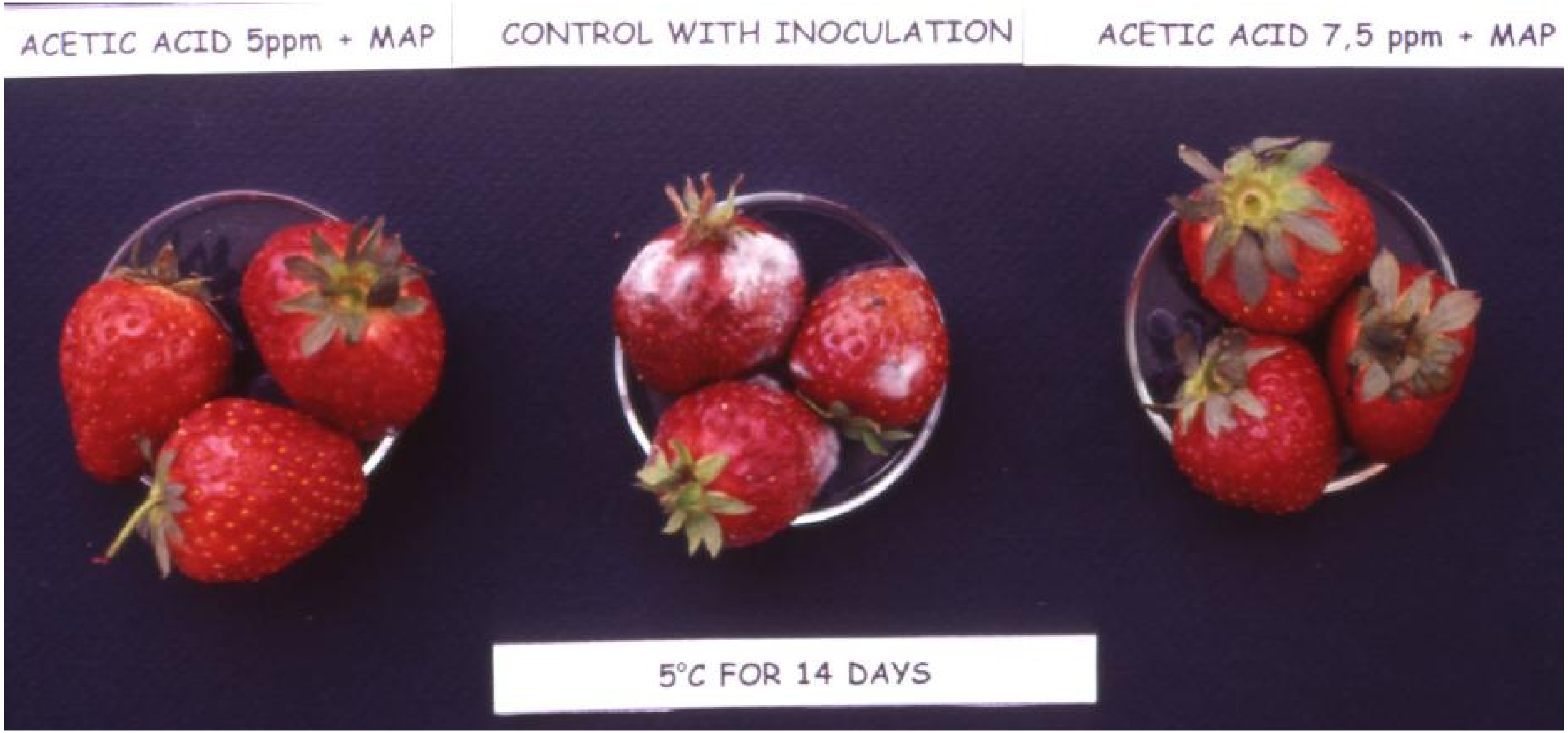
Problems: for products with shelf life greater than the suggested by the producer there is risk for product spoilage and growth of bacteria.

• Further research is needed for the development of new films/equipment and combination treatments to cover all the horticultural produce.

• Intelligent packaging

Combination treatments

- Use pre-treatments in combination with MAP to improve safety and shelf life
- Avoid contamination
- Synergistic effect



Intelligent packaging systems

Development of "smart films" that have the ability either to absorb or to emit gases and vapours.

New techniques:

- Oxygen scavenging
- Carbon dioxide formation
- Off-flavor removal
- Ethylene removal
- Ethanol emitters
- Water removal
- Edible films